The Importance of Obtaining Relevant Sensitivity Data in Conducting Hazards Analysis of Explosives Processes

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ABSTRACT

The OSHA administered rule 29 CFR 1910.119, "Process Safety Management of Highly Hazardous Chemicals," requires manufacturers of hazardous chemicals, including explosives, to conduct process hazards analyses of potentially hazardous operations. The process hazards analysis must address the hazards of the process and provide a qualitative evaluation of the range of the possible safety and health effects. The principle hazard when processing ammunition or explosives is initiation of the material with subsequent potential for fire or explosion. To address the hazards of processing ammunition or explosive materials adequately, an understanding is needed of the sensitivity and response of the material to initiating energies associated with failure modes in the process. Relevant sensitivity testing should be conducted on the ammunition or explosive materials to determine its threshold initiation levels to the applicable initiating energies. The sensitivity testing should be conducted on test apparatuses and using test methodologies with which the analyst is well versed and knowledgeable. This knowledge is essential if the analyst is to correlate the data to the process being analyzed. The sensitivity data should be presented in engineering units to allow direct comparison of the sensitivity data with in-process potential energies associated with identified process failure modes. Once all the relevant data is obtained, comparison of the sensitivity data to the in-process potential energies will yield a likelihood of explosives initiation for a given failure mode. Once a likelihood of initiation is determined, and knowing the ammunition or explosive quantity and response, the consequence of an accidental initiation can be inferred. Combining these results with process safety information and risk mitigation recommendations constitutes a qualitative hazards analysis that ammunition and explosives processors can use to make decisions on safety questions and on the allocation of safety resources. Through the use of qualitative hazards analyses, costs associated with over-conservatism and invalid assumptions can be reduced or eliminated. The result is better control of risks to personnel, facilities, and product.

INTRODUCTION

The Occupational Safety and Health Administration (OSHA), Department of Labor, is administrating a new rule issued by Congress and put in to effect as an amendment to the

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Clean Air Act. This rule, 29 CFR 1910.119, is named "Process Safety Management of Highly Hazardous Chemicals" and it contains specific requirements for preventing or minimizing the consequences of catastrophic releases of toxic, reactive, flammable, or explosive chemicals. The rule was written for processes that involve specific hazardous chemicals at or above a specified threshold quantity, but it also applies to the processing, handling, and storage of ANY quantity of explosives.

Central to the new Process Safety Management (PSM) rule is the requirement to conduct process hazards analyses of potentially hazardous operations. These hazards analyses must address: (i) The hazards of the process; (ii) The identification of any previous incident which had a likely potential for catastrophic consequences in the work place; (iii) Engineering and administrative controls applicable to the hazards and their interrelationships; (iv) Consequences of failure of engineering and administrative controls; (v) Facility Siting; (vi) Human factors; and (vii) A qualitative evaluation of a range of the possible safety and health effects of failure of controls on employees in the workplace.

To conduct the hazards analysis, the employer is further required to use one or more of the following analysis methodologies to determine and evaluate the hazards of the process being analyzed:

- (i) What-If;
- (ii) Checklist;
- (iii) What-If/Checklist;
- (iv) Hazard and Operability Study (HAZOP);
- (v) Failure Modes and Effects Analysis (FMEA);
- (vi) Fault Tree Analysis; or
- (vii) An appropriate equivalent methodology.

DISCUSSION

When processing, handling, or storing ammunition or energetic materials, such as pyrotechnics, propellants, or explosives, the range and severity of accident scenarios associated with these processes are usually dependant on initiation of the material from an energetic stimulus, coupled with the speed of the response (or yield) of the material and the quantity of material present. By conducting qualitative hazards analyses of ammunition or explosives processes, potential accident scenarios can be identified and modifications can be made to eliminate or minimize the severity of the identified hazards.

To conduct hazards analyses of ammunition or explosives processes and have them meet the requirements of the Process Safety Management rule, the process must be analyzed using one of the approved methodologies. The choice of an analysis methodology depends on complexity of the process and on the skill of the analyst in using a particular methodology. A hazards analysis of a simple process using a Checklist is fairly easy and can be conducted by most anyone familiar with the processes. Conducting a Failure Modes and Effects Analysis of a complex process is more involved and requires a trained and experienced analyst. Once a methodology is chosen, the process is analyzed for failure modes, that could result in accidental initiation of the ammunition or explosive material, using the methodology to guide the analysis.

To determine if an identified failure mode could cause initiation of ammunition or explosive materials being processed, information is needed on the sensitivity of the materials to the relevant initiating energies resulting from the failure mode. Ammunition and explosives initiating energies include such energies as impact, friction, heat, incompatibility, radio frequency (RF) energy and electrostatic discharge. Failure modes responsible for such initiation energies can be due to mechanical failures, process control failures, explosives contamination, coupling of RF energies into electrical explosive devices, human error, or broken or missing equipment grounds. In searching for this sensitivity data, sources are severely limited. Of the existing sources, many different testing apparatuses and testing methodologies are used to obtain the data.

A series of sensitivity tests, that are required for ammunition and explosives to obtain shipping authorization, are the Department of Defense (DOD) and Department of Transportation (DOT) Explosives Hazard Classification Tests. These tests are used to determine the reaction of ammunition and explosives to specified initiating influences. Based on the reactions obtained, the ammunition and explosives are assigned an appropriate hazard classification. Explosives Hazard Classification Tests include the Detonation Test, Ignition and Unconfined Burning Test, Thermal Stability Test, Impact Sensitivity Test, Card Gap Test, Single Package Test, Stack Test and External Fire Stack Test. These tests are mainly used to determine ammunition and explosives reaction to initiating influences, but they also provide a degree of initiation sensitivity data. This is particularly true with the impact sensitivity test and to a lesser degree, with the thermal stability test and the single package and stack tests. The resultant sensitivity data, however, only provides "order of magnitude" type results. These results identify that an explosive material is sensitive to a specific initiating influence, but they do not determine at what input energy level sensitivity begins.

The DOD and DOT Explosives Hazard Classification Impact Sensitivity Test, for example, references the use of a Bureau of Explosives impact apparatus that drops an eight-pound weight and subjects the explosive material to 10 individual drop tests from a height of 3 ¾-inches. The explosive material is considered impact sensitive if a positive reaction (smoke, fire, or explosion) occurs in more than 50% of the 10 trials. No attempt is made to determine how sensitive the material is, that is, at what impact energy initiation begins.

Other general sources of ammunition and explosives sensitivity data can include Hazardous

Component Safety Data Statements (HCSDS) for Military Ammunition and Explosives, Military Explosives Manual TM 9-1300-214, Army Materiel Command Pamphlet 706-177 "Properties of Explosives of Military Interest" and the International Pyrotechnics Societies: "Properties of Selected High Explosives." The problem with using these general sources, or data from several sources, is that the data is often incomplete and test apparatuses and test methodologies are rarely referenced.

It is important that the hazards analyst, using the sensitivity data, have a good understanding of the test apparatus and test methodologies used to obtain the data. Choice of test apparatus and test methodology, as well as the test conductor, can greatly affect obtained sensitivity results. Some impact test apparatuses, for example, use electromagnets to hold and drop steel balls of various weights, while others use a consistent weight that slides down guide rails. And, the drop heights are varied. Depending on the choice of test apparatuses, obtained sensitivity results will vary. The Bureau of Explosives (BOE) Impact Apparatus, referenced for the DOD and DOT Hazard Classification Test, will give slightly different sensitivity values, then will be obtained using a modified Bureau of Mines (BOM) Impact Apparatus. The main difference in obtained results between the two impact machines is partially a result of the BOE apparatus typically uses a sample holder for holding the explosives sample during testing, while the BOM impact test machine does not.

The BOE sample holder is a multi-piece component made up of a holder primer, upper anvil, two spacers, lower spacer and lower anvil. The effect of using a sample holder during an impact test, is that the sample holder provides a degree of confinement to the sample. Confinement of the sample can result in an increase in sensitivity, as the material is less able to dissipate imparted impact energy. Since more of the delivered energy is confined in the sample, the sample is more likely to initiate at a lower impact energy than if unconfined.

Use of a sample holder will also complicate the determination of the amount of impact energy delivered to the sample. Impact sensitivity is usually expresses as the minimum height of fall of a given weigh necessary to cause initiation. While using a sample holder, through, some attenuation of the impact energy delivered will occur due to all the interfacing components of the holder primer, upper anvil, etc., in the sample cup. The impact energy delivered to the explosive material sample will be some portion of the energy supplied by dropping the weight. With the many interfacing components, calculation or measurement of the actual energy delivered to the sample is difficult.

To account for the inability to accurately determine the amount of energy delivered to the explosives sample, results obtained using the Bureau of Explosives impact apparatus are quite often referenced back to "being more (or less) sensitive than a control material tested on the same apparatus." Such data with comparison provides only a relative sensitivity that does not easily lend itself to calculations of initiation likelihood or probability.

The Modified Bureau of Mines Impact Apparatus differs from the Bureau of Explosives apparatus through its use of a five kilogram drop weight dropped directly onto the test sample that is placed directly on an impact anvil. The BOM apparatus also incorporates a dropped

weight rebound catching mechanism that catches the dropped weigh on its first rebound from striking the sample, so that the sample is only subjected to a single impact.

Since a sample holder is not used on the modified BOM impact apparatus, more of the impact energy is delivered directly to the sample. This impact energy also can be easily estimated based on calculation. A close approximation of the impact energy delivered to the sample is the product of the weight of the drop weight times the height from which the weight was dropped, divided by the impact area of the drop weight on the impact anvil. The impact energy delivered on the modified BOM impact apparatus can also be directly measured. By replacing the impact anvil on the BOM machine with an impact force gauge and dropping the drop weight directly onto the force gauge, a direct measurement of the impact energy can be made. The resultant value by either method will not be the exact amount of energy delivered to the sample, as not all of the energy will go into initiating the sample, but the value determined will be a much closer approximation then can be obtained using the multi-piece sample holder on the Bureau of Explosives impact apparatus.

With a knowledge of the test apparatus, the strengths and limitations inherent in the apparatuses can be taken into account when the data is used in an analysis. If sensitivity data is obtained from a wide variety of sources, with no knowledge of the apparatuses used, inaccurate assumptions may be concluded, based upon the data obtained, that could invalidate the resulting hazards analysis.

Sensitivity data obtained from various testing apparatuses can also be presented in such a form that makes comparison of the data to actual in-process conditions difficult. The Roto-Friction Test Apparatus, is used by some laboratories to express the sensitivity of an explosive material to friction as a relative sensitivity value, Eq. Eq is the square of the frictional energy required to cause a sample to react, multiplied by the time rate at which the energy is applied. The smaller the Eq product, the more sensitive the explosive material is to friction.

The units given for the relative friction sensitivity obtained from the Roto-Friction apparatus are $(ft\text{-}lb)^2/sec$. Again, such sensitivity test results cannot be directly compared with in-process conditions, nor can a calculation of initiation likelihood or probability be made. As the results are so relative, they are usually reported as a given Eq product, "which is more (or less) sensitive than a control explosive material tested on the same apparatus."

A method for determining friction sensitivity data that allows for direct comparison with in-process conditions, is through the use of a sliding plate friction apparatus, such as the Hercules Allegheny Ballistic Laboratories (ABL) Friction Test Apparatus. The ABL Friction Test Apparatus is referenced in the United Nations Manual, "Transportation of Dangerous Goods and Test Criteria," as the United Nations Standard for friction test apparatuses. The ABL friction test apparatus subjects an explosives material sample to a predetermined normal force, in psi, combined with a horizontal sliding component at some feet per second, usually either 4 ft/sec or 8 ft/sec. Results of the ABL Friction Apparatus provides sensitivity values for the explosives material with the data being given in engineering units of psi @ ft/sec (or $newtons/m^2$ in the mks system). Having the sensitivity data reported in relevant engineer

units, makes comparison of material sensitivity to in-process potential energy direct and meaningful.

Another area where choice of test apparatuses can affect sensitivity test results is with electrostatic discharge test machines. At the present time, more than one test method is used to determine electrostatic sensitivity. In all of the methods, a spark gap is formed between an electrode and the explosives sample. A capacitor is charged to a specific voltage then discharged through the gap. Both the size of the capacitor and the voltage are varied to vary the energy in the spark. Depending on the size of the capacitor and the voltage level a specific energy discharge can be produced. Care must be taken, however, in choosing a capacitor/voltage configuration. A large capacitor charged to a low voltage, can generate the sample discharge energy, as a small capacitor charged to a large voltage. The resultant rate at which this energy is discharged, however, will vary. A long duration spark, caused by using a large capacitor charged to a low voltage, will result in different sensitivity values, than will a short duration spark, caused by a small capacitor charged to a high voltage.

Variations also exist as to what constitutes a positive test result. Some test apparatuses rely on the test conductor to determine whether an explosives sample reacted, i.e., generated either smoke, fire, or explosion. This determination can be difficult when the test sample is confined in a sample holding cup, or is located within the test apparatus, or, as in the case of the electrostatic discharge test, where the delivery of the initiation energy itself is fairly energetic. To address this problem, some test apparatuses use electronic detectors to measure the degree of reaction. The Light Infrared Analyzer (LIRA) manufactured by MSA Pittsburgh PA., is used by some testing laboratories to "sniff" the off-gasses of the combustion products generated during a sensitivity test. Sensitivity test results obtained using a LIRA will be more accurate and may result in a greater reported sensitivity, than will results obtained relying only on the test conductor to detect positive responses.

Besides differences in test apparatuses and test result detection, there are also differing test methodologies used with test apparatuses to determine explosive material sensitivity. A test methodology such as the Bruceton Method, uses a down, up, and down testing approach to zero in on initiation energies. Using the Bruceton method, an explosives sample is subjected to an initial energy and if a reaction occurs, the energy is decreased in incremental steps and the test is repeated until no reaction is obtained. The energy is then increased again to assure that the material reacts. The energy level is then decreased to the level at which no reaction occurred and 10 trials are conducted at that energy level to assure that no reaction occurs. The sensitivity level for the explosive material is then usually reported as the level at which there were "all fires" during 10 trials and at the energy level at which "all no fires" occurred during the 10 trials.

Bruceton Method types of test methodology provide more information on the sensitivity of an energetic material than does the order of magnitude test results of the DOD and DOT Hazard Classification Tests. The limited number of tests conducted with such methods, though, still introduces a statistical degree of uncertainty into the data with regard to the actual threshold initiation level of the explosive material. Reporting of the sensitivity level at the level where

"all no fires" occurred in 10 trials, also implies that below this value no initiations will occur. This may not always be true. A standard distribution of initiation energies would say that as energy levels are decreased, the probability of an initiation decreases, but it does not immediately go to zero. As only 10 trails were conducted at the level where no reactions occurred, if more trails had been conducted, it is possible that additional reactions could have occurred.

Very rarely, an explosive material also may exhibit split or dual levels of initiation sensitivity. It has been observed that some explosives will show sensitivity at an energy level, below that level the sensitivity will decrease and then further below that the material will again show sensitivity. If insufficient sensitivity testing is conducted, the split sensitivity characteristic could be completely missed. The explosive material would then be more sensitive than believed, which could invalidate the conclusions of a hazards analysis based on the incomplete sensitivity data.

When conducting sensitivity tests of explosive materials for use in qualitative hazards analyses, more is needed to be known other than that the material is relatively sensitive to a specific initiating energy, or that it is more (or less) sensitive than a similar explosive material tested on the same apparatus. Also, knowing that the explosive material confined in a sample holder will initiate when impacted with an eight pound weigh dropped from a height of 3 ¾-inches, revels nothing about what would be expected if the drop height were reduced to two inches or even ¼ inch or if the sample holder were not used. An empirical sensitivity value, such as the Eq product obtained from the Roto-Friction apparatus, is only useful as a relative value and can not be directly compared to any operating in-process potential. To be of use in conducting a qualitative hazards analysis, sensitivity testing needs to determine the energy level at which explosives initiations begin, the level below which initiations are unlikely and just how unlikely they are.

A testing methodology that supplies the type of sensitivity data suitable for direct use in qualitative hazards analysis is Probit testing. Using Probit testing methodology, sensitivity tests are conducted on an explosive material for 10 trials at an initial input energy level. The number of reactions obtained at that energy level during the 10 trials are recorded, i.e., 8/10. The input energy is then lowered an incremental amount and the test is repeated for an additional 10 trials, again, recording the number of reactions obtained at that energy level during the 10 trials, i.e., 6/10. This procedure is continued until an input energy level is reached at which no reactions occur in 20 trials, i.e., 0/20.

When using the Probit test methodology, the threshold initiation sensitivity for the explosive material, or that energy above which initiations become likely, is reported as that energy level at which no reactions occurred in 20 trials. Reporting the threshold initiation sensitivity at this energy level, rather than at a greater energy such as the Bruceton "all fire" and "all no fire" levels during obtained 10 trials, introduces an additional degree of safety conservatism into the testing and removes some of the statistical uncertainty present in the sensitivity data.

With Probit sensitivity data, statistical uncertainty of an explosive material's response to an

initiating stimulus can be further reduced, as the sensitivity is determined and recorded over a range of input energies. The resultant sensitivity data can then be plotted and extrapolated, and a full range of sensitivity, at a given probability, can be obtained. Probit test methodologies, with results reported in engineering units, provide conservative threshold initiation level data that can be directly compared to in-process potential energies of identified failure modes, so a determination can be made as to likelihood of explosives initiation for a given failure mode.

Generating Probit data of the impact or friction sensitivity data obtained from sensitivity tests using an impact apparatus (like the modified BOM apparatus or a friction apparatus like the ABL friction machine), is preferable for use in qualitative hazards analyses, over simply conducting the Hazard Classification Tests or Bruceton methodology tests on these same apparatuses. A probit chart of sensitivity verses probability of initiation for a specific explosive material can give the probability of initiation of the material over a large range of input energies, to a calculated confidence level of 95%.

When obtaining explosives material sensitivity data for use in qualitative hazards analyses, it is, therefore, important to know which type of test apparatus and test methodology was used. Obtaining data from multiple, unrelated sources should be discouraged as the results may not be relevant to the failure mode being analyzed. Data obtained from general access sources such as Hazardous Components Material Safety Data Sheets or technical manuals also are only as good as the quantity of information provided as to test apparatus and test methodology used.

It is recommended that sensitivity data be obtained from a single source. Choose a reliable testing laboratory. One that uses consistent test apparatuses, test methodologies and high trained testing technicians. Require that the sensitivity data be reported in engineering units. Then, stick with that laboratory for all your sensitivity testing needs. Sensitivity data obtained from a single source will, over a period of time, result in the generation of a sensitivity data base that allows meaningful relative comparisons. Sensitivity data obtained in such a way can be directly compared to in-process potential energies of failure modes identified in qualitative hazards analysis and a determination can be made of initiation likelihood.

Once likelihood and consequence of a particular failure mode has been determined, a qualitative hazards analysis can be assembled. Within this hazards analysis, a process description is given, the failure modes with likelihood and consequences are identified, process safety information is included and process or material modifications to eliminate or reduce the severity of identified risks are recommended. With incorporation of the recommendations from the hazards analysis, a potential explosive incident can be avoided or reduced in severity.

Equipped with qualitative hazards analyses that are supported by relevant sensitivity data, explosives processors are in a better position to make decisions on safety questions and on the allocation of safety resources. Costs associated with over-conservatism and invalid assumptions can be reduced or eliminated. The result is better control of risks to personnel,

facilities, and product.

An example of where obtaining relevant sensitivity data has been applied and resulted in increased safety and a significant savings is with a pyrotechnic charging operation of a military projectile at the Lake City Army Ammunition Plant. A new military projectile charging operation undergoing acceptance testing, was being charged with a high explosive and a pyrotechnic mix. Coincidental with the initial stages of the projectile testing and acceptance program, an improved heating, ventilation, and air conditioning (HVAC) system was installed in the manufacturing building where the projectiles were being charged. This new HVAC system provided a capability to control the humidity. Provided with this new capability, management decided to increase the humidity in the building, with the intent controlling electrostatic charging hazards. The combination of the higher humidity level with the already incorporated extensive equipment and operator grounding was expected to provide redundant protection against accidental electrostatic discharge initiation of the explosive material.

As soon as the humidity was increased, quality problems surfaced. The projectiles began to fail test firing performance criteria. Engineering investigations of the failed test firings led them to suspect the increased humidity as the cause of the reduced performance, as it was the only parameter that had recently been changed. Projectiles charged prior to increasing the humidity met performance requirements, while those charged after the humidity was raised did not. One theory presented was that the pyrotechnic mix contained a perchlorate oxidizer which was highly hygroscopic and the perchlorate was absorbing moisture from the high humidity, which, in turn decreased the performance of the pyrotechnic. An additional safety concern raised was that the pyrotechnic mix contained powdered magnesium and that exposure of powdered metals to moisture could cause spontaneous initiation. Engineering then requested a hazards analysis be conducted to determine the risk from operating the pyrotechnic charging operation at 40% relative humidity.

For this hazards analysis, since the scope and process were fairly well defined, the necessary information required was the sensitivity of the pyrotechnic mix to electrostatic discharge. Small samples of the pyrotechnic material were sent to a test laboratory specializing in threshold initiation level sensitivity testing. Since the pyrotechnic material was already being sent for electrostatic discharge testing, it was agreed that the sample would also be tested for friction, impact, and autoignition.

The results of the sensitivity testing were that the pyrotechnic mix turned out to be only moderately sensitive to electrostatic discharge. The threshold initiation level was determined to be 0.65 joules. For comparison, the industry standard for an electrostatic discharge from a human is conservatively placed at 0.01 joules. This value for human discharge can be calculated from the capacitance, C, of the human body of 10 picofarads, and the electrostatic voltage, V, to which the body can be charged, of 20,000 volts, using the equation for energy, $E = 1/2\ CV^2$.

EQUATION

$$
\begin{aligned}
\textit{Where } E &= \frac{1}{2} CV^2 \\
&= \frac{1}{2}(10\,pf)(20{,}000\,volts)^2 \\
&= 0.002\ joules \\
&\approx 0.01\ joules
\end{aligned}
$$

The safety factor for accidental initiation of the pyrotechnic mix due to operator electrostatic discharge can be calculated from the pyrotechnic mix threshold initiation sensitivity value of 0.65 joules, divided by the potential electrostatic discharge energy from a charged operator of 0.01 joules. The safety factor for electrostatic discharge initiation for the above scenario was, therefore, 65. The 0.65 joule threshold initiation level of the pyrotechnic mix was 65 times the electrostatic discharge energy capable of being discharged from a human body. As electrostatic charging was already being adequately controlled through equipment and operator grounding, the humidity in the building was lowered, and the projectile once again began passing acceptance testing.

An unanticipated result of also performing the sensitivity testing for impact, friction, and autoignition, was that the testing determined that the pyrotechnic mix was extremely sensitive to friction. The pyrotechnic mix had a friction threshold initiation level of 10 psi @ 4 ft/sec. Review of the charging process with respect to friction initiation, showed the charging unit to be fraught with areas where pyrotechnic dust could collect and be subjected to frictional forces. Recommendations were in the resulting hazards analysis to eliminate pyrotechnic dusting, which could be subjected to frictional forces and lead to accidental initiations.

Conducting a qualitative hazards analysis of this operation identified that the real risk with this pyrotechnic charging process had to do with frictional initiation, rather than electrostatic charging as was previously assumed. Conducting the qualitative hazards analysis using relevant sensitivity data not only helped management in its decision to remove the conservatism of the unneeded high humidity constraints, but also it identified a previously unrecognized frictional initiation hazard that had a high likelihood of accidental initiation with subsequent potential for fire or explosion.

REFERENCES

1. U. S. Department of Labor, 29 CFR 1910.119, "Process Safety Management of Highly Hazardous Chemicals," May 26, 1992.

2. Department of the Army Technical Bulletin 700-2, "Department of Defense Explosives Hazard Classification Procedures," December 1989.

3. System Safety Society, "System Safety Handbook," July 1993.

4. Department of the Army Military Standard 882B, "System Safety Program Requirements," 28 June 1977.

5. Col. T. M. Weekly, "Guidance Pertaining to Development of Hazards Analysis for Ammunition/Explosives Operations," Department of the Army Memorandum, Ref. No.: AMSTE-ST (385-10d), 11 May 1992.

6. Department of the Army, "Hazards Analysis for Facilities, Equipment and Process Developments," DARCOM-R 385-3, 16 November 1981.

7. Department of the Army, "Military Explosives," TM 9-1300-214, September 1984.

8. Department of the Army, "Properties of Explosives of Military Interest," Army Materiel Command Pamphlet 706-177.